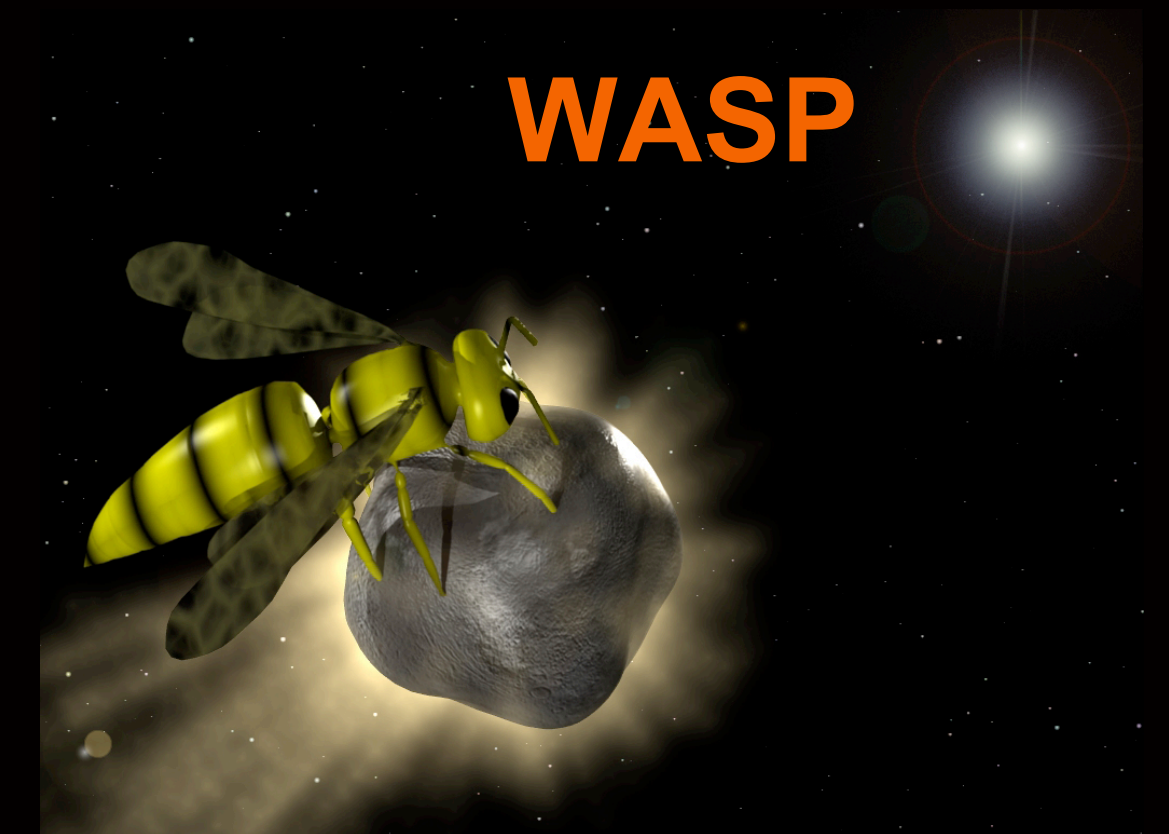


The Wirtanen Analysis and Surface Probe: Concept for a New Frontiers Comet Surface Sample Return Mission

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SCIENCE OBJECTIVES

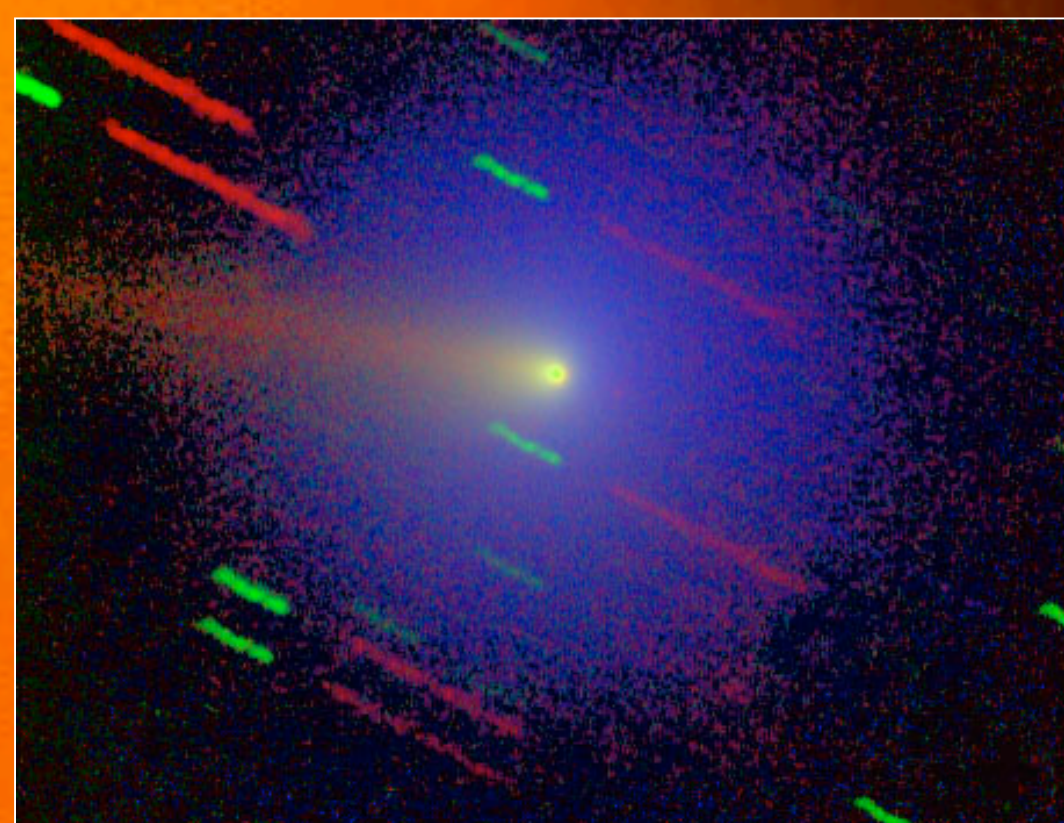
The material contained within the surfaces of comets holds keys that unlock fundamental questions regarding the formation of the Solar System and life on Earth. Comets contain primordial material from the formation of the Solar System [1], as well as many volatile and organic compounds [2] that are inconsistent with models of Solar System accretionary processes [3].

The primary mission objective for the Wirtanen Analysis and Surface Probe is to obtain a sample of the comet's surface and deliver that sample, uncontaminated, back to Earth. The science objectives of WASP (shown below) focus on the analyses possible once the sample is safely returned. While some science objectives can be met in situ, most require successful return of the sample for laboratory analysis.

- Detect and characterize organic materials
- Determine D/H, other isotopic ratios of ice and other surface materials
- Determine the penetration depth of solar and cosmic radiation
- Determine the abundance and characteristics of preexisting materials
- Determine cometary grain and regolith sizes
- Determine the age of cometary surface materials
- Determine the mineralogy and composition of cometary material
- Identify the source of cometary gas vents and the composition of local material surrounding vents
- Determine the shape and gravity field of the comet Wirtanen's nucleus

Delivery of organics by comet and asteroid impacts are believed to be an important step in the development of life on Earth; of primary importance to the WASP mission is the detection and characterization of organic and prebiotic molecules. In addition to addressing these fundamental issues in astrobiology, Solar System evolution, and solar nebula dynamics, WASP will provide invaluable insight into cometary composition, evolution, and dynamics. A thorough investigation of Wirtanen's structure, surface composition, and dynamic evolution will serve to inform theoretical models and direct experimental inquiry for scientists in astronomy, planetary science, and astrobiology.

Figure 1: Comet Wirtanen



MISSION PROFILE

The Wirtanen Analysis and Surface Probe (WASP) is a comet surface sampling mission designed to return 0.5 to 1.0 kg of cometary surface material to Earth on a New Frontiers budget of \$750 million. WASP is designed for a 8.84 year round trip mission to 46/Wirtanen. Our mission architecture, chosen to optimize science and sample return capabilities, consists of a combined Comet Orbiter & Lander (COAL) that first engages Comet Wirtanen in a sixty-day orbit. After a landing site is selected, the entire COAL lands, anchors itself to the surface, and obtains a sample. After sample collection, the Earth Return Vehicle - containing only the necessary subsystems for Earth return - is ejected from the lander and sent on a 4 year trajectory back to Earth. The Earth Entry Vehicle (EEV), consisting of only the return capsule, is ejected 36 hours prior to atmospheric entry.

MISSION SUMMARY		
LABEL	EVENT	DATE
1	Launch	04/26/2015
2	Venus Flyby 1	08/25/2015
3	Venus Flyby 2	12/16/2015
4	Earth Flyby	01/17/2019
5	Comet Close Approach Phase	08/22/2019
	Comet Rendezvous at 3.2 AU	11/28/2019
	COAL Landing & Surface Sampling	01/26/2020
6	ERV Separation & Departure	01/27/2020
7	EEV Separation	Earth Return - 36 hrs.
8	Earth Return	12/15/2023

Table 1: WASP mission timeline

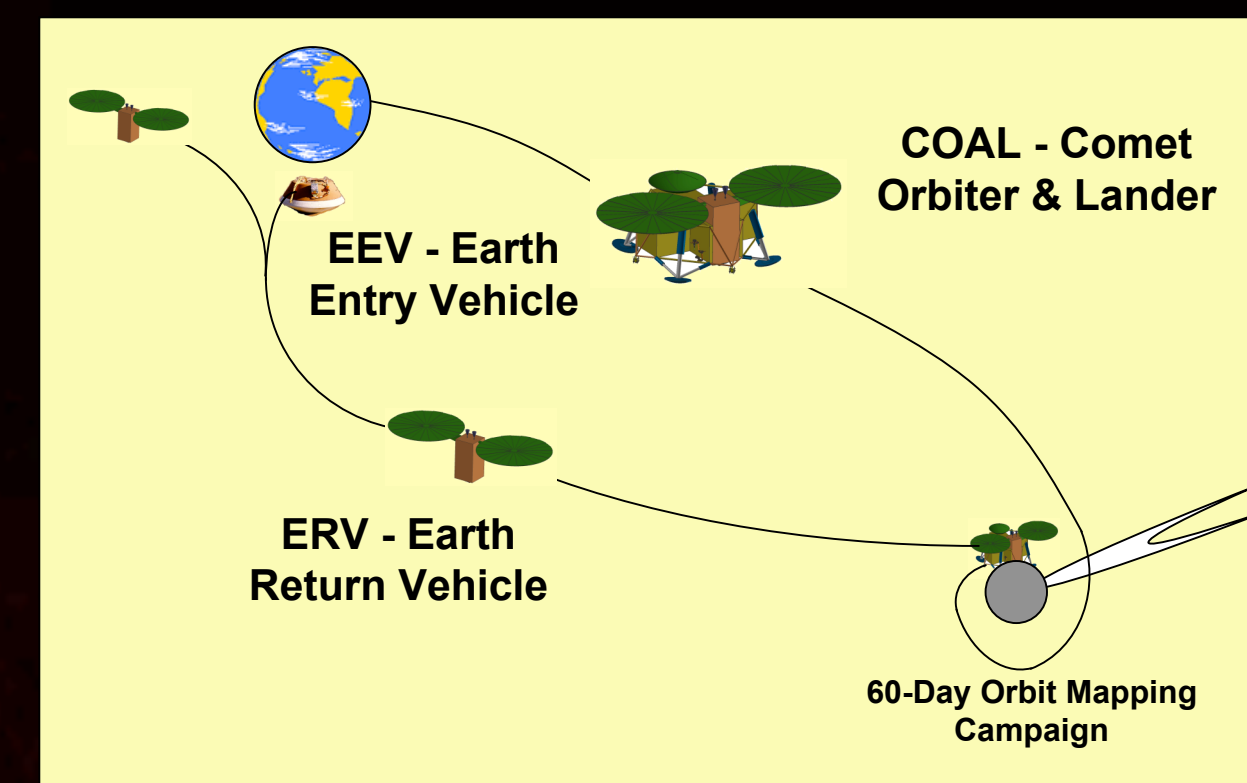


Figure 2: WASP mission overview

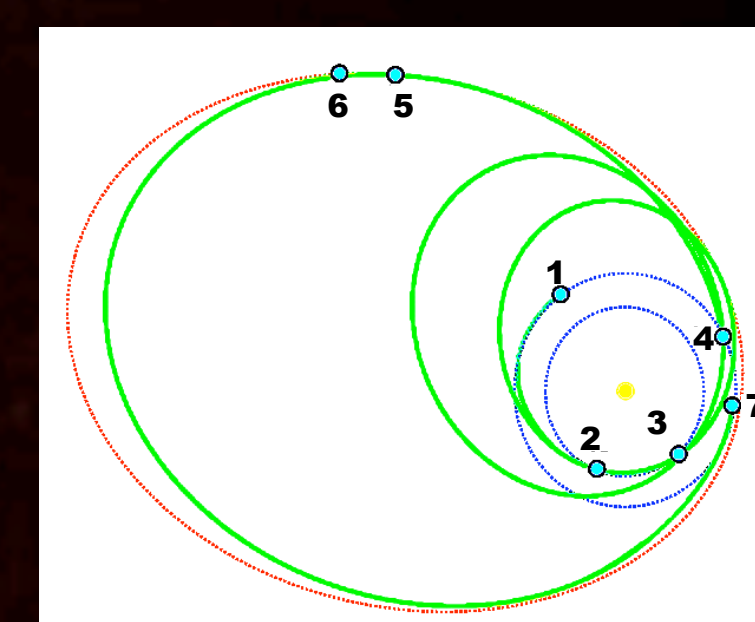
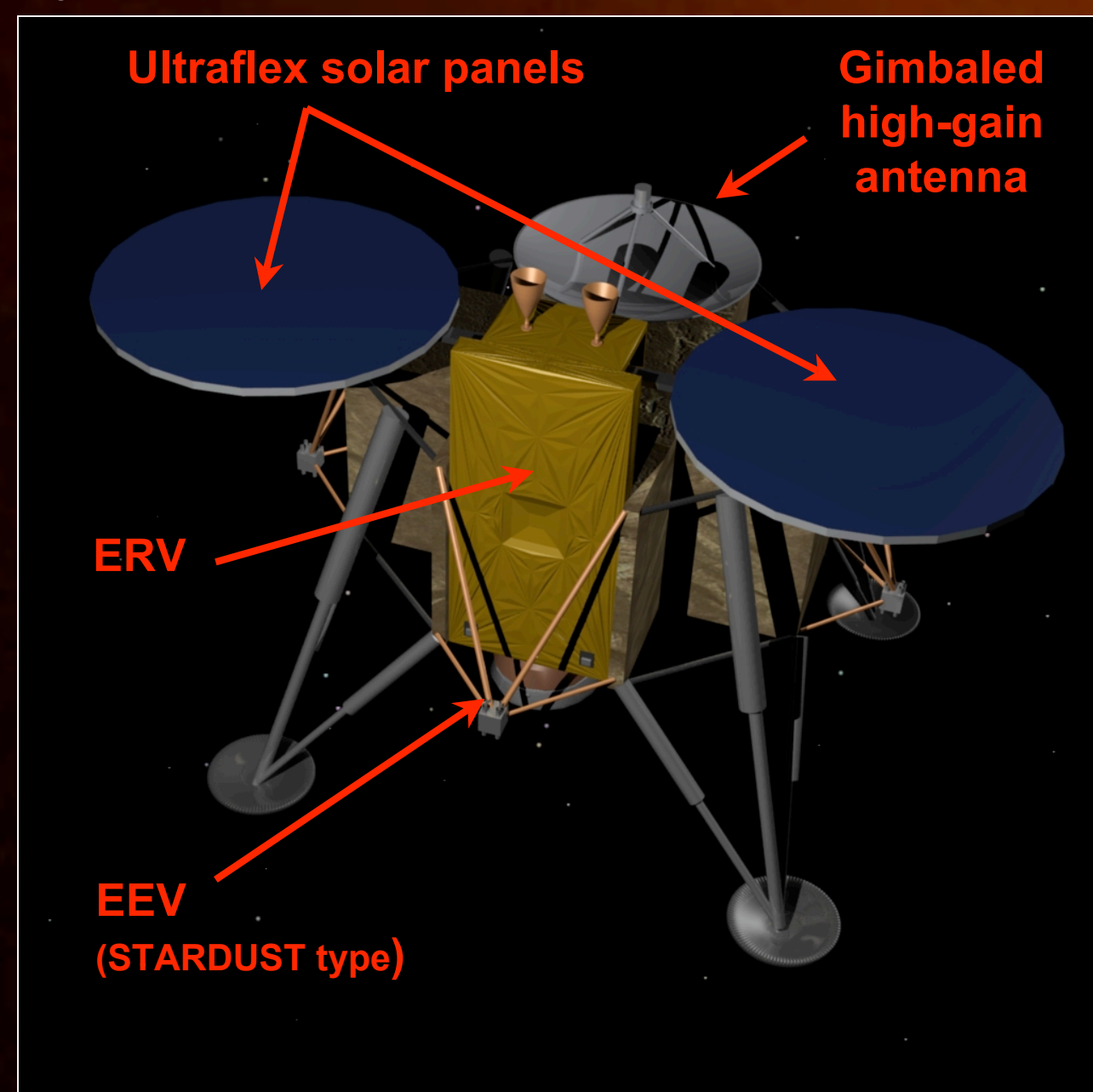


Figure 3: WASP orbital trajectory

LANDING SEQUENCE

Figure 4: COAL Comet Lander (top view)



Once the Comet Orbiter & Lander (COAL) arrives at the comet, it begins mapping the nucleus. Two medium field cameras map the surface and obtain stereographic images to characterize comet nucleus morphology and identify landing sites. After a sixty-day reconnaissance of the comet, the Comet Orbiter & Lander (COAL) begins its descent sequence. The ultraflex solar panel are retracted to prevent off-axis deflection of the lander on approach. The COAL lands, anchors itself to the surface with a Rosetta-type harpoon, and unfurls its solar panels for a 24-hour stay on the surface (3 comet rotations). The COAL then begins transmitting images of the surface for selection of a sampling site with two wide-angle ground observation cameras.

SAMPLING MECHANISM & RETURN CAPSULE

A critical component of a successful comet sample return mission is the sampling mechanism and return capsule. Our team considered a variety of sampling mechanisms including: drills, penetrators, fly wheel brushes, and a robotic arm/scoop mechanism. While it would be ideal to have a variety of sampling mechanisms to account for a variety of surface types, we found that such a design would have a prohibitive development cost associated with it.

After considering factors such as ability to sample at various depths, flight system complexity, and development cost, we chose a robotic arm/scoop mechanism. The robotic arm/scoop has a strong design heritage using the PHOENIX arm and scoop as a template for our design. The scoop is a "clam shell" design that closes and inserts as a unit into the sample capsule after visual verification of sample acquisition of 0.5 to 1 kg of surface material.



Figure 5: Sample collection and insertion into ERV

The sample capsule also has a strong design heritage with the Genesis and Stardust missions capsule as our base design. Most of the development cost associated with the sampling mechanism and return capsule would be the "clam shell" scoop, and an insertion mechanism to deposit the scoop/sample into the capsule.

DEPARTURE & EARTH RETURN

After sampling is completed, the Earth Return Vehicle (ERV), including the attached Earth Entry Vehicle (EEV), is spring ejected from the anchored COAL and is set on a 4 year return trajectory to Earth. The EEV separates 36 hours prior to atmospheric entry. The capsule enters the atmosphere at 15 km/s.



Figure 6: ERV ejection



Figure 7: EEV separation

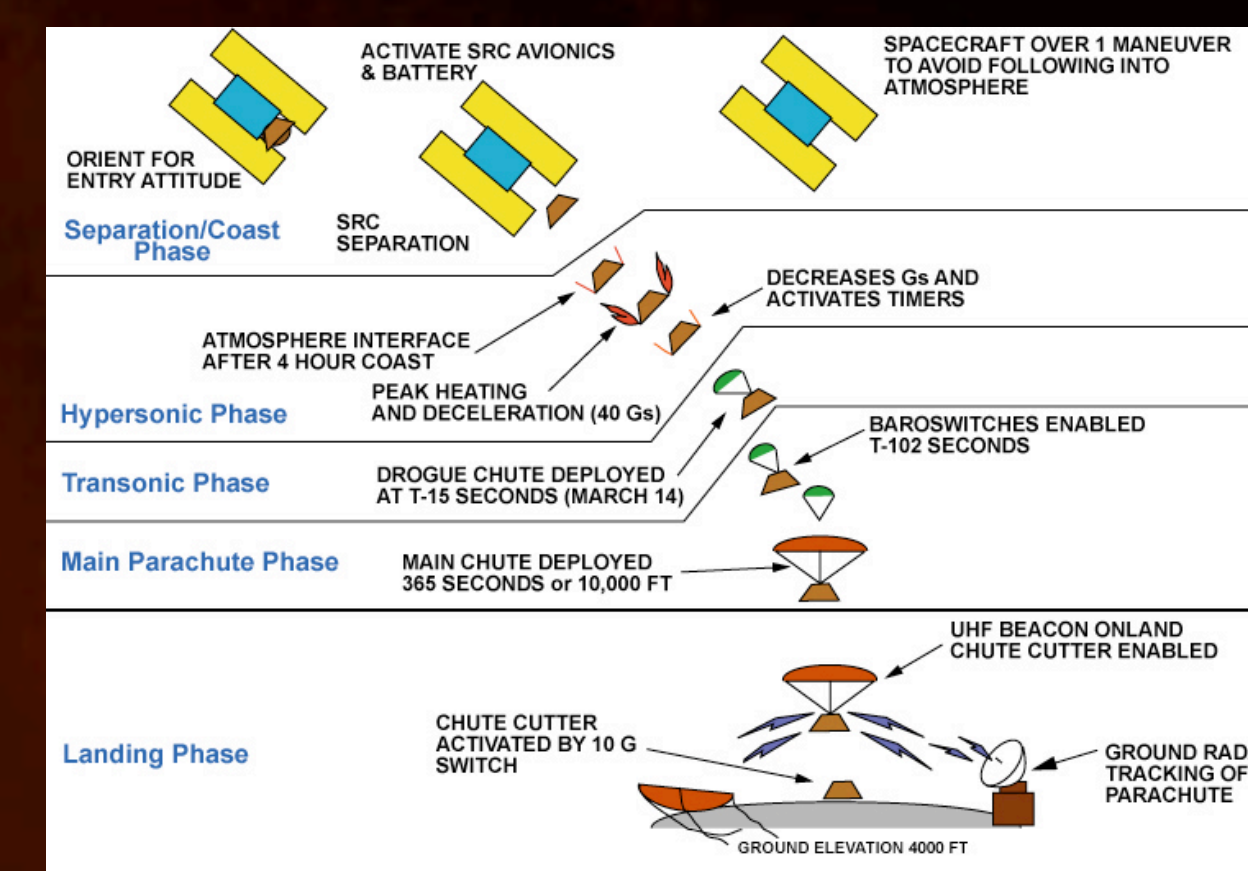
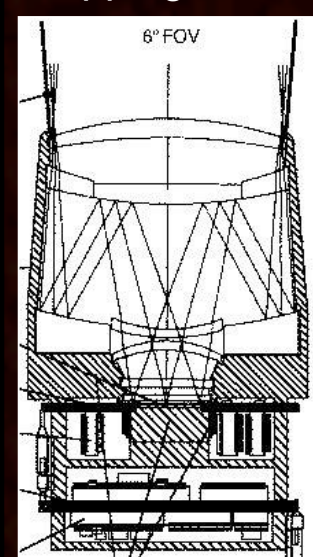


Figure 8: Earth atmospheric entry and landing sequence (Stardust capsule)

INSTRUMENTS & TECHNOLOGY

Figure 9: Mapping camera



Two 6°- FOV cameras

- MARCI/MRO heritage
- Used to stereoscopically map the comet surface from orbit during a 60-day campaign prior to landing

Figure 10: MER HAZCAM image



Two wide-angle ground observation cameras

- HAZCAM/MER heritage
- Used to guide landing and confirm sample collection

Figure 11: PHOENIX arm and scoop



Multi-joint arm (PHOENIX heritage)

- "Clam-shell" scoop (new design)
- Used for sample collection and stowage

SPACECRAFT MASS BREAKDOWN

The fully loaded COAL spacecraft weighs 1802 kg at launch. This mass can be launched to escape velocity by an Atlas V-521 booster with a 30% payload margin. The Earth Return Vehicle (ERV) represents 581 kg of this total, including ERV propellants.

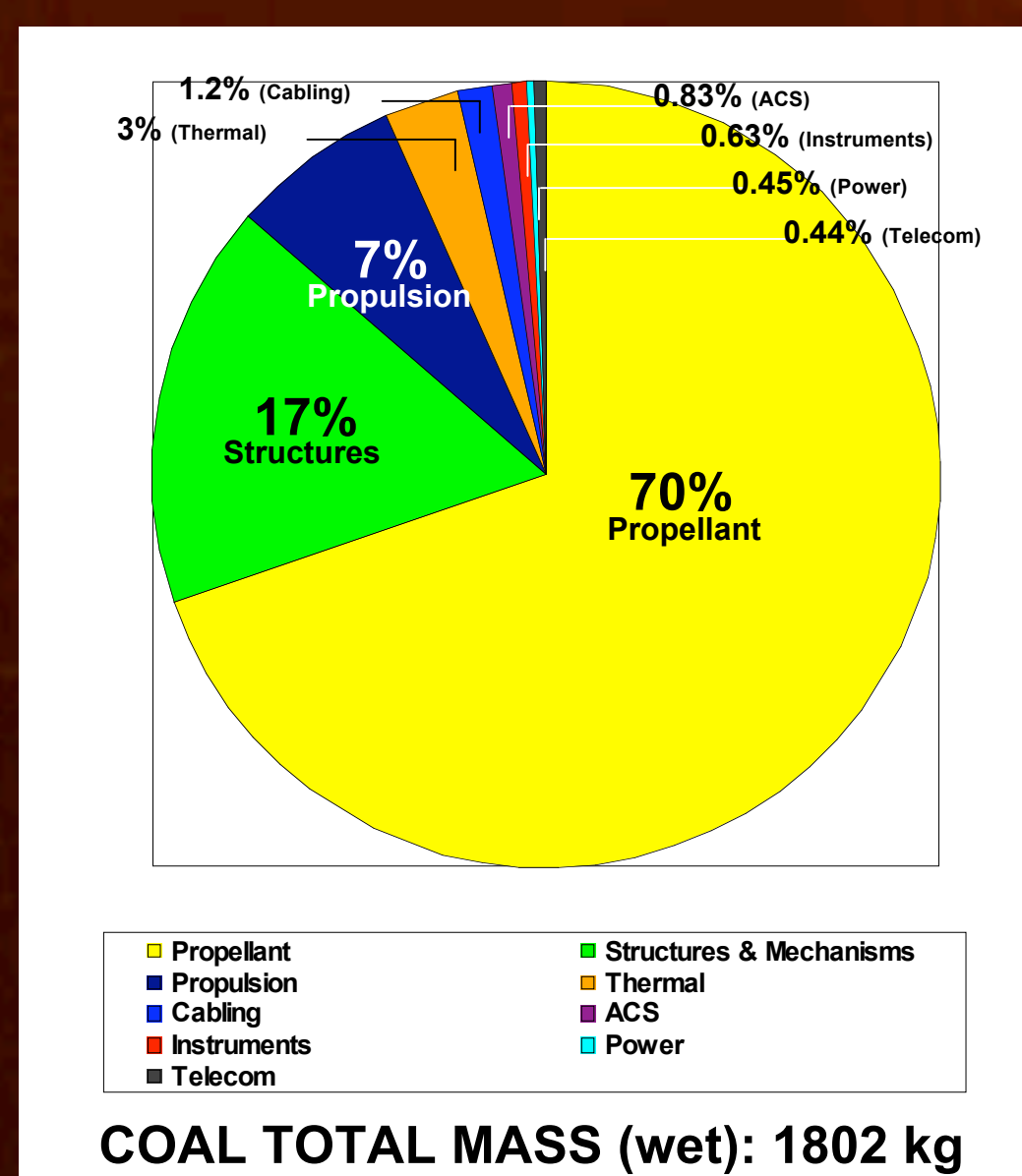


Figure 12: COAL launch mass breakdown

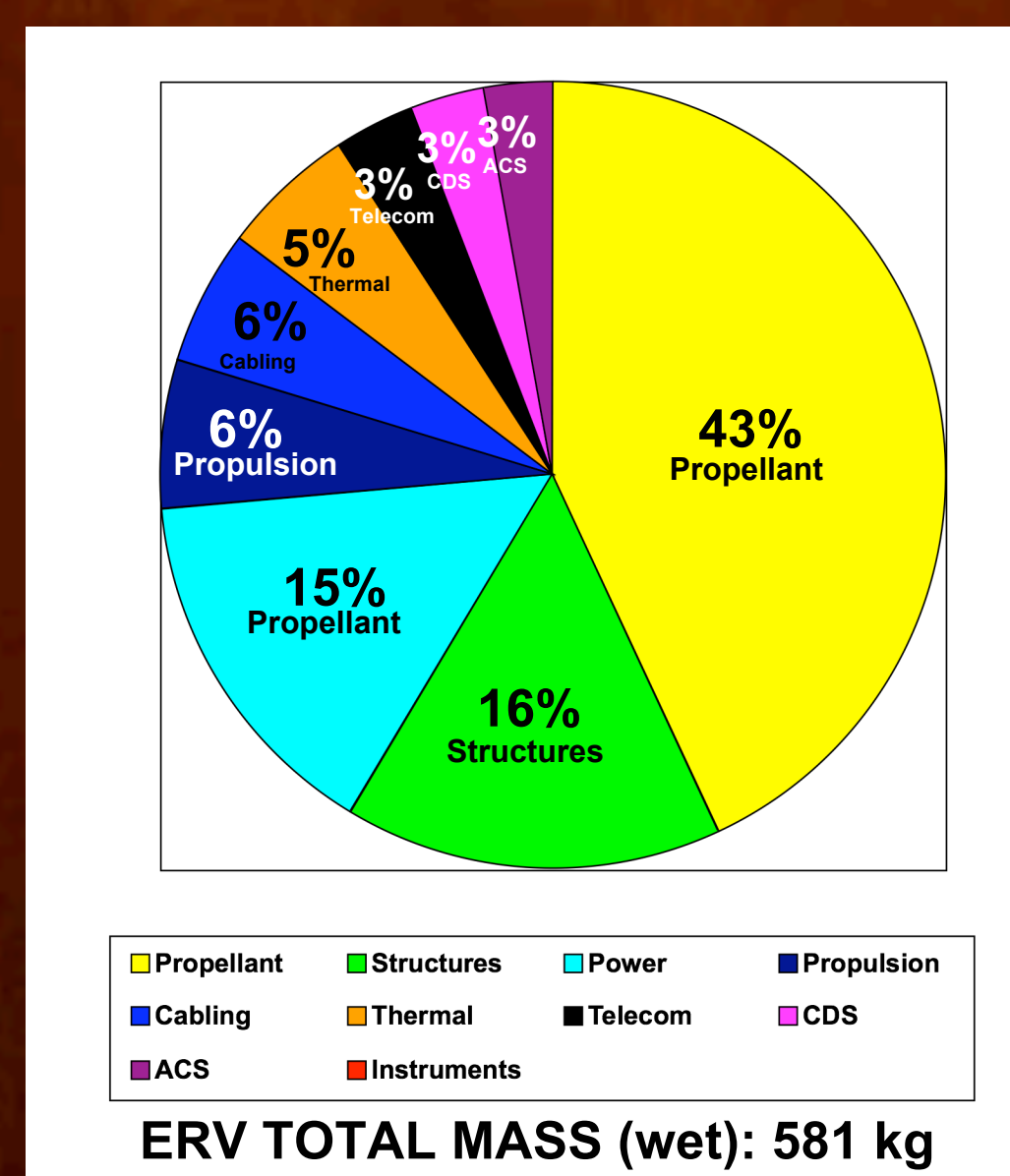


Figure 13: ERV launch mass breakdown

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